Response of Thermospheric Hydrogen to Solar Variability and Greenhouse Gases

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Overview

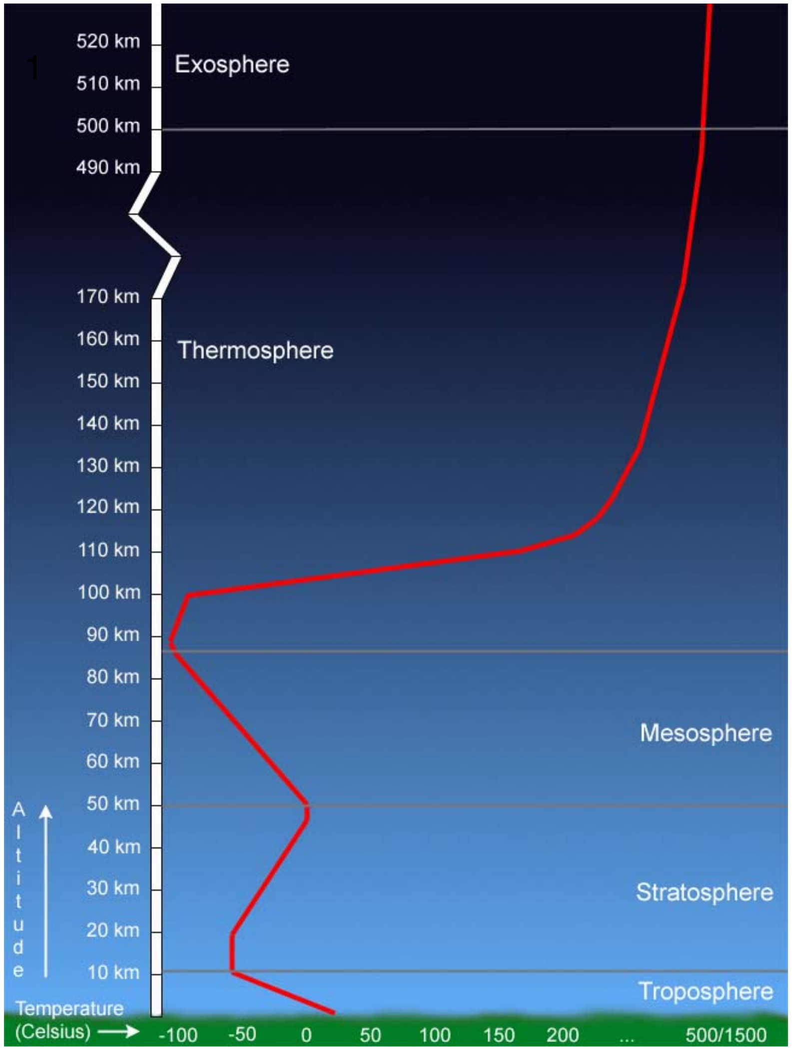
What are the solar cyclic and climatic influences on lower to upper atmospheric coupling of hydrogenous species?

What are the solar cyclic and possibly longer-term trends in emission observations from geocoronal hydrogen, the upper boundary of the Earth's hydrogenous species distribution?

- Hydrogen species budget and coupling
- NCAR Global Mean Model sensitivity studies
- WI Northern hemisphere long timeline data set
- Conclusions
- Ongoing/future work

Coupling of hydrogen-containing species

1



4

Atomic hydrogen becomes increasingly dominant with altitude

3

CH_4, H_2O, H_2 chemistry & photolysis reactions

2

Sources of methane include: Agriculture, fossil fuels, waste treatment, biomass burning, wetlands

[1]Courtesy of Windows to the Universe, http://www.windows.ucar.edu

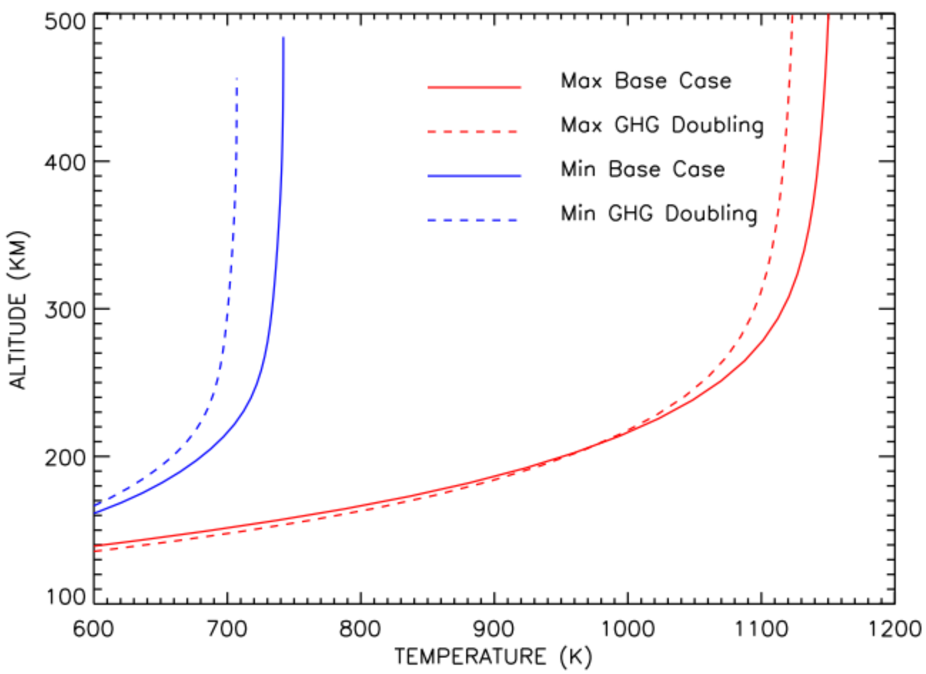
[2]from: http://earthobservatory.nasa.gov/Features/BiomassBurning/

Online: http://www.britannica.com/ebc/art-95671

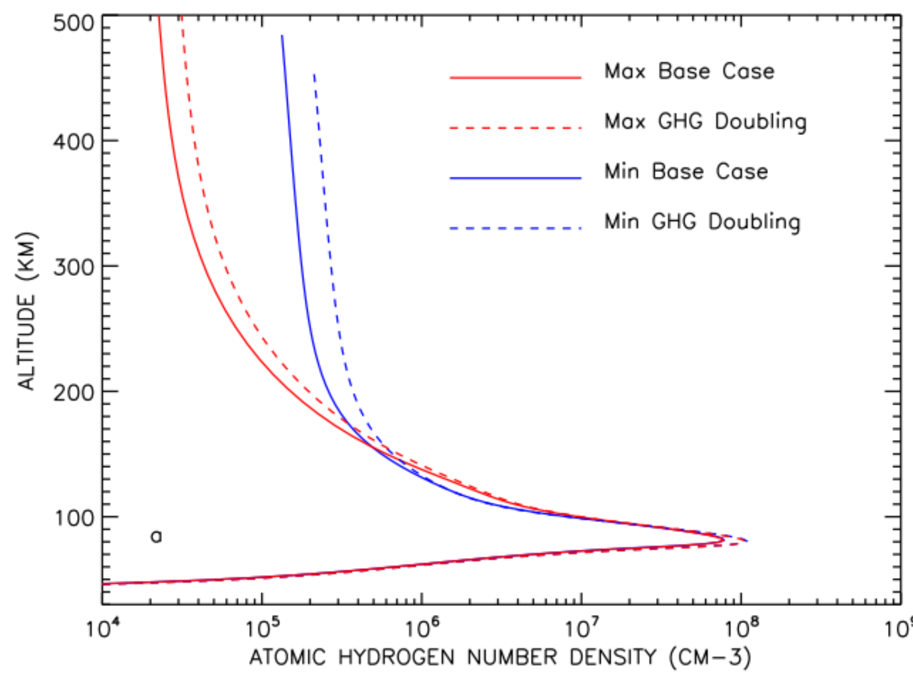
[3]© Pekka Parviainen From http://lasp.colorado.edu/noctilucent_clouds/

[4]Source: Carruthers, Page, and Meier, Apollo 16 Lyman alpha imagery of the hydrogen geocorona, J. Geophys. Res., 81, 1664, 1976. and . pluto.space.swri.edu/.../ apollo_geocorona2.gif

Modeled Temperature and Atomic Hydrogen Density Profiles



Temperature

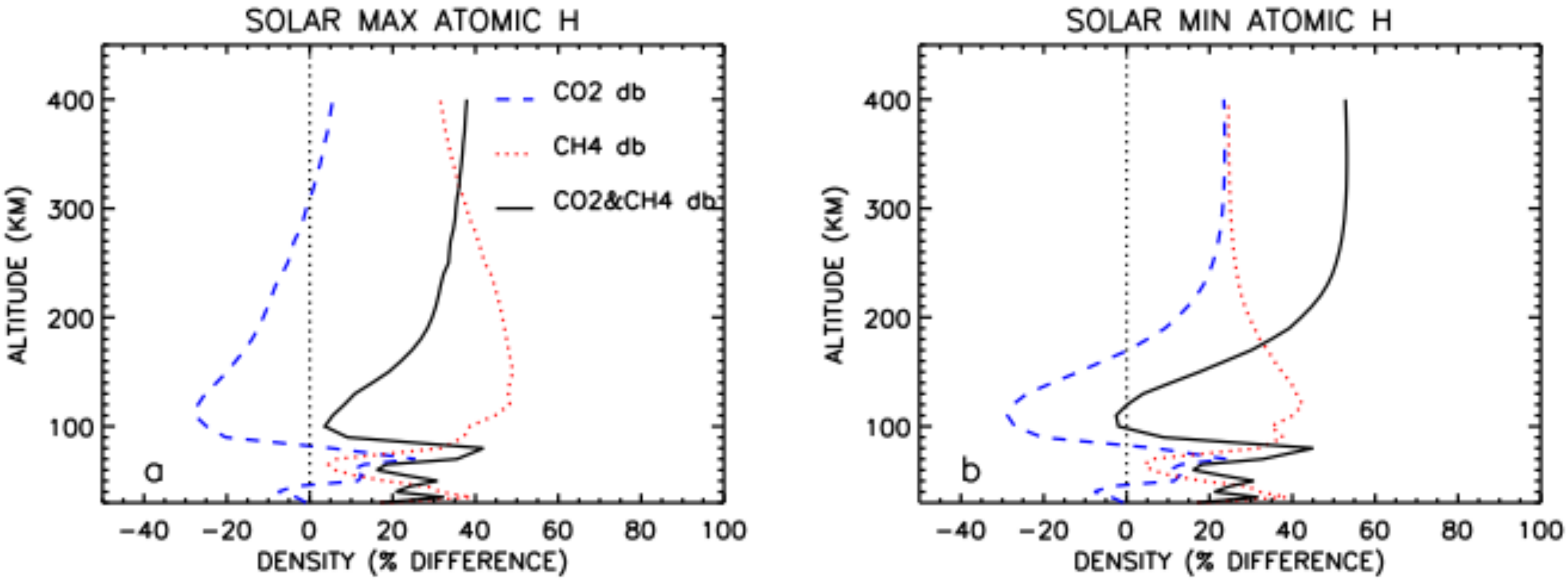


Atomic hydrogen

Nossal et al., 2016

Solar Cyclic changes in both T and H are greater than with GHG doubling.

NCAR Global Mean Model: Atomic hydrogen



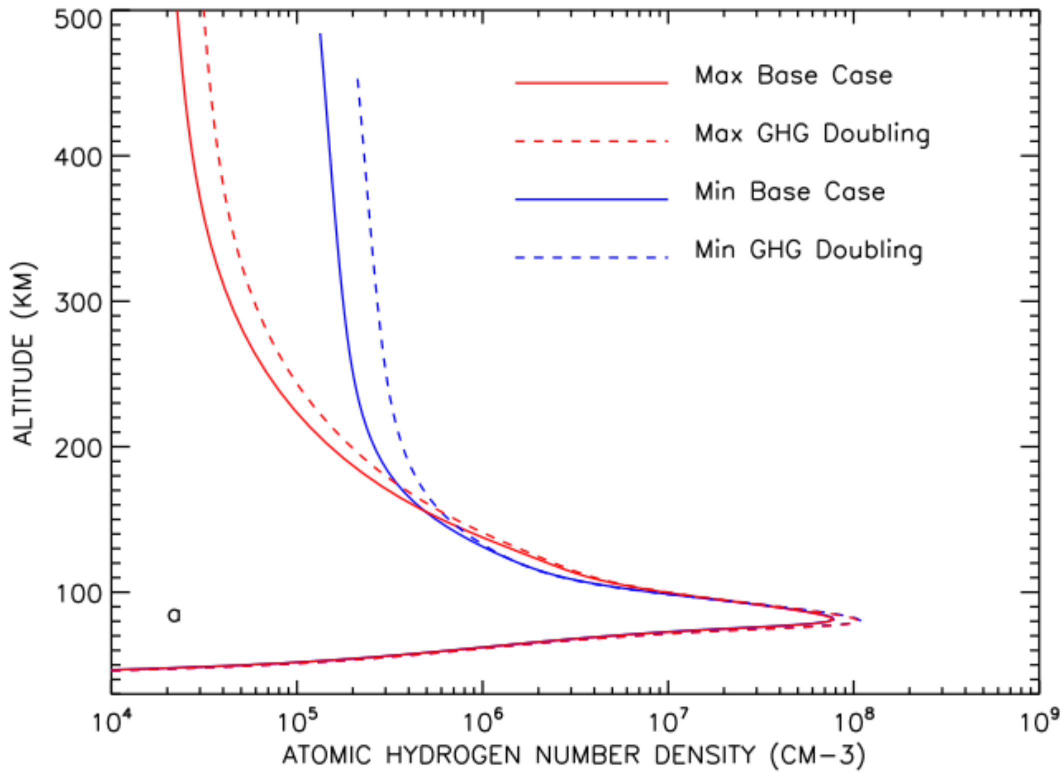
- Percent difference: ([H] doubling scenario - [H] base)/[H] base.

- **Carbon dioxide cooling & methane both lead to predicted increases in H**

- **H response to GHGs depends on phase of solar cycle**

[*Nossal et al., JGR,* 2016]

Modeled Atomic Hydrogen Density Profiles



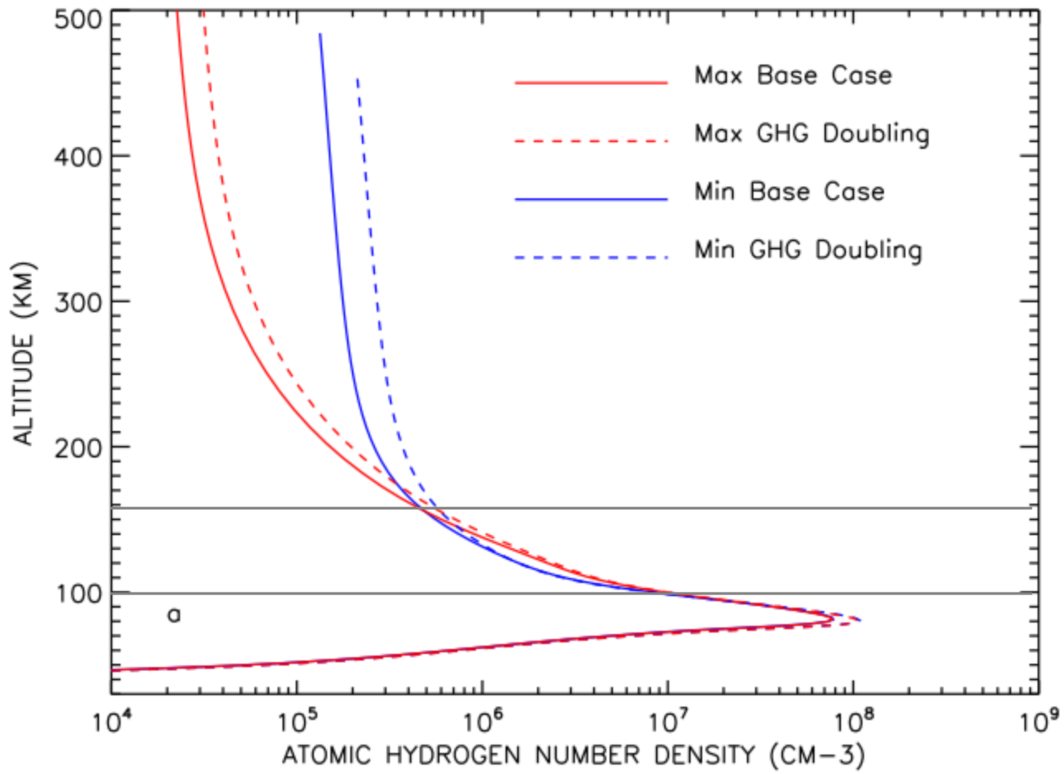
- H density (log) for base case and GHG doubling scenarios for both solar min and max.

The H distribution changes over the solar cycle

- more H in lower thermosphere at max

- more H in upper thermosphere at min

Modeled Atomic Hydrogen Density Profiles



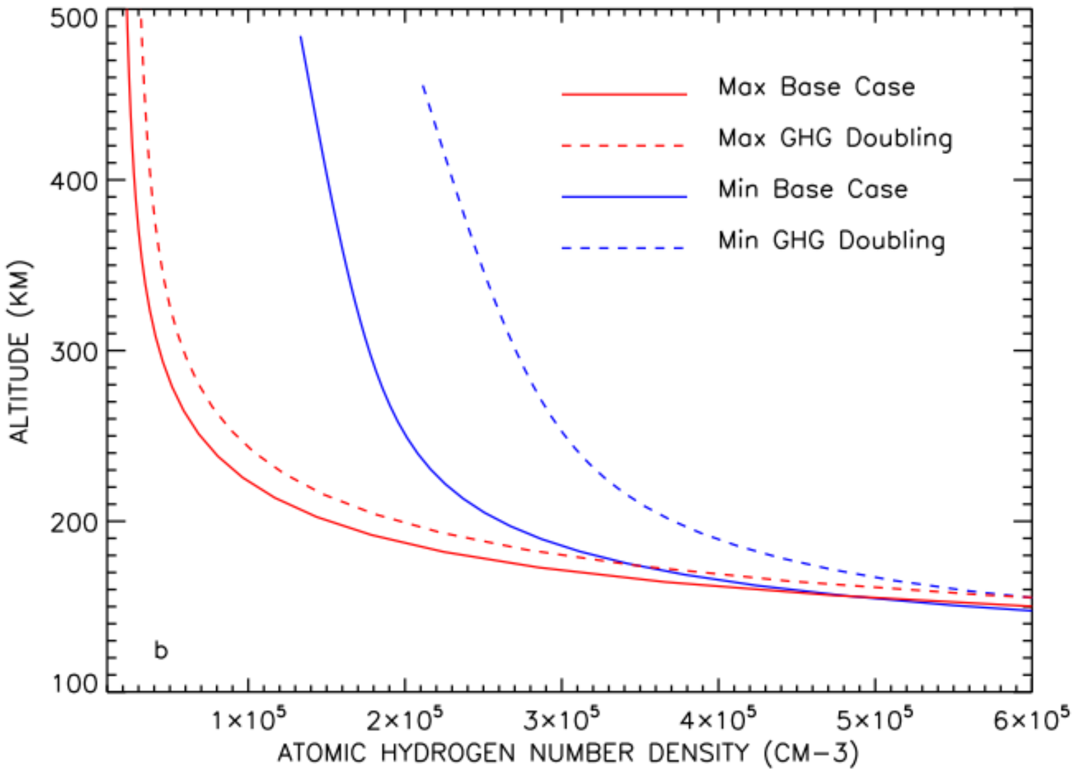
• H density (log) for base case and GHG doubling scenarios for both solar min and max.

The H distribution changes over the solar cycle

- more H in lower thermosphere at max

- more H in upper thermosphere at min

Modeled Upper Thermospheric Atomic Hydrogen Density



• H density (linear) for base case and GHG doubling scenarios for both solar min and max.

Increase in H absolute density due to GHG doubling is greater at min.

Wisconsin Long Timeline Hydrogen Balmer-alpha data set

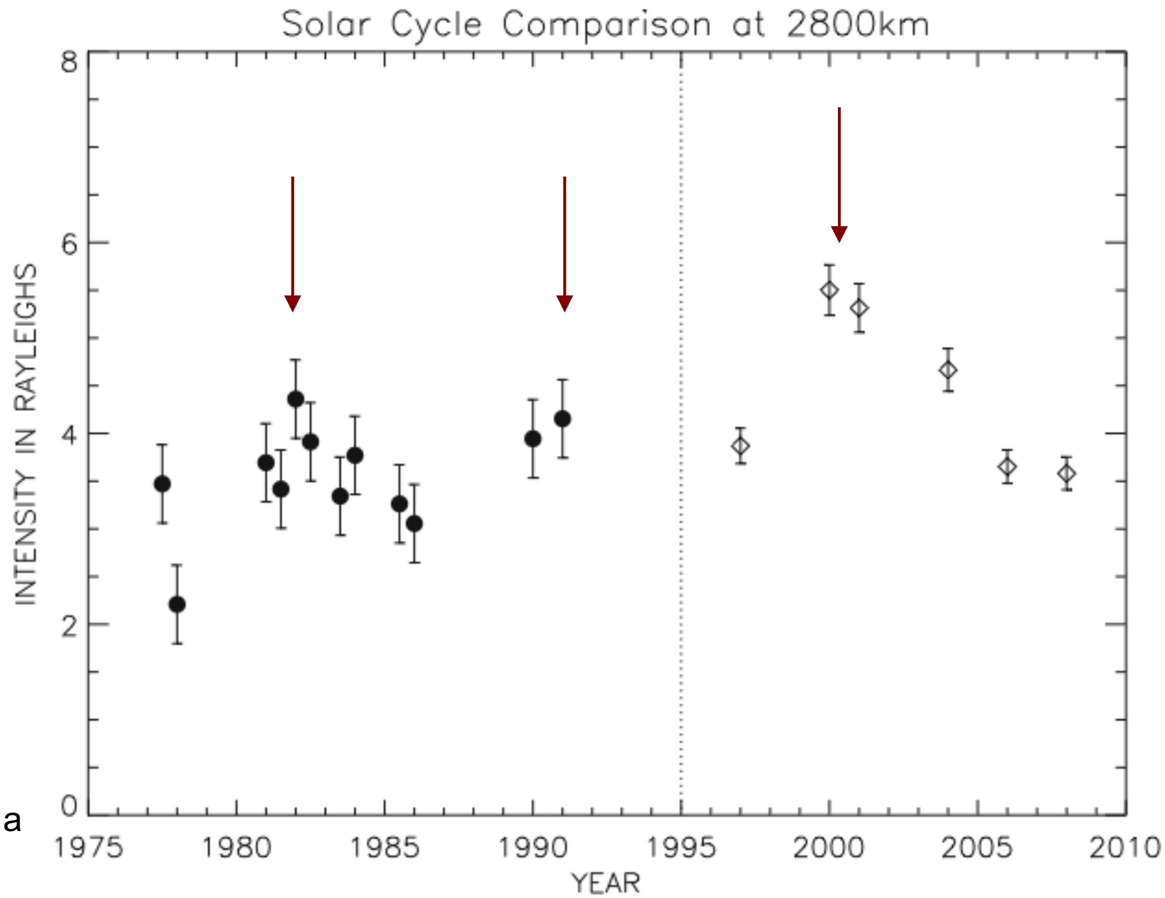


Fig. a

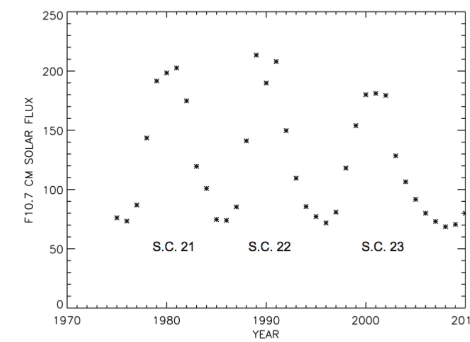
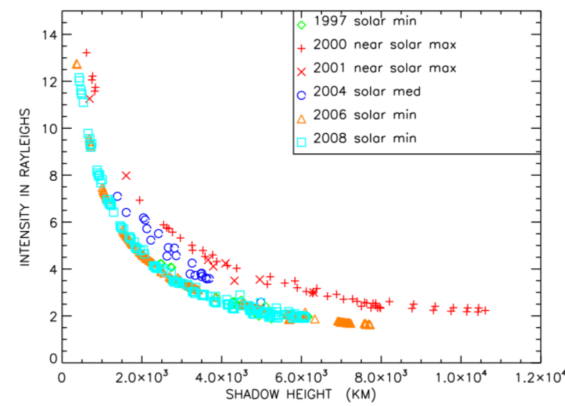


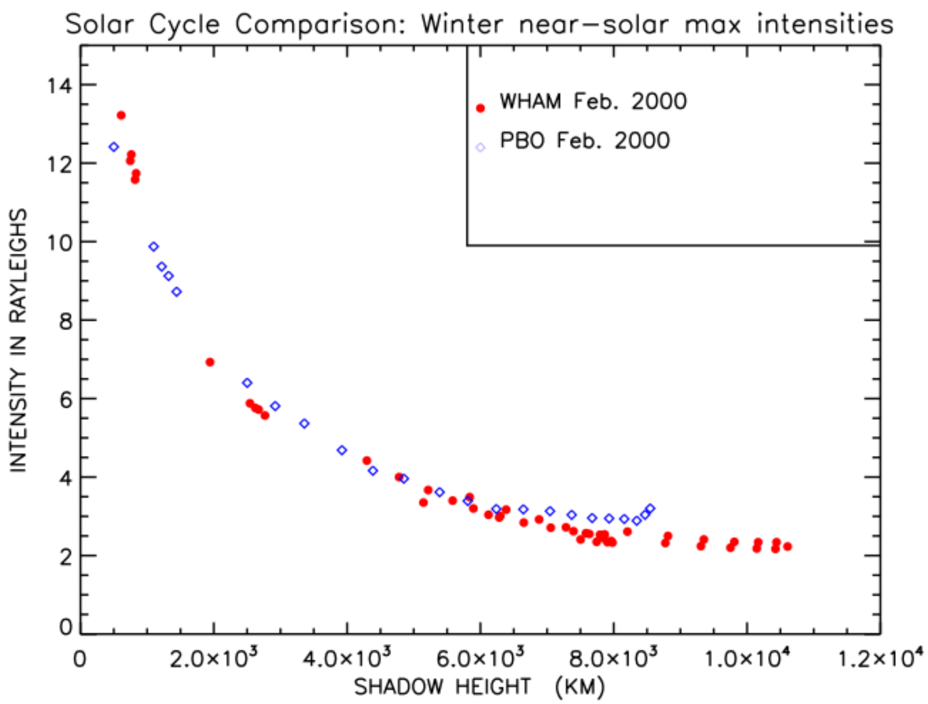
Fig. b

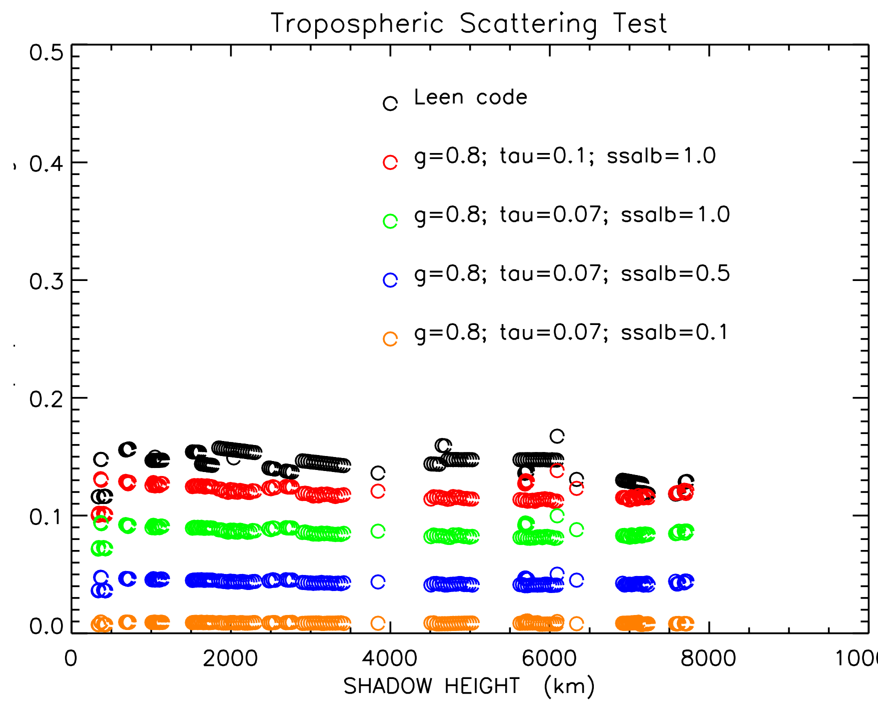
Yearly averaged F10.7 cm flux



- Figure a: Hα column emission intensity at a mid-range shadow altitude vs. year. Observations on the right were taken with WHAM and those on the left were taken with the scanning "pre-WHAM" Fabry-Perot. Error bars indicate uncertainty in the determination of the relative intensity. **Each point represents multiple nights and spectra.**

Hydrogen Balmer α observations from WI and Kitt Peak





Woodward et al., in progress

Hα column emission intensity observed from Wisconsin and Arizona during same observing period.

The WI Northern hemisphere data suggest an increase that has not been accounted for by uncertainties due to experimental factors, including calibration, tropospheric scattering, cascade fine structure excitation and Galactic emission.

Wisconsin Long Timeline Hydrogen Balmer-alpha data set

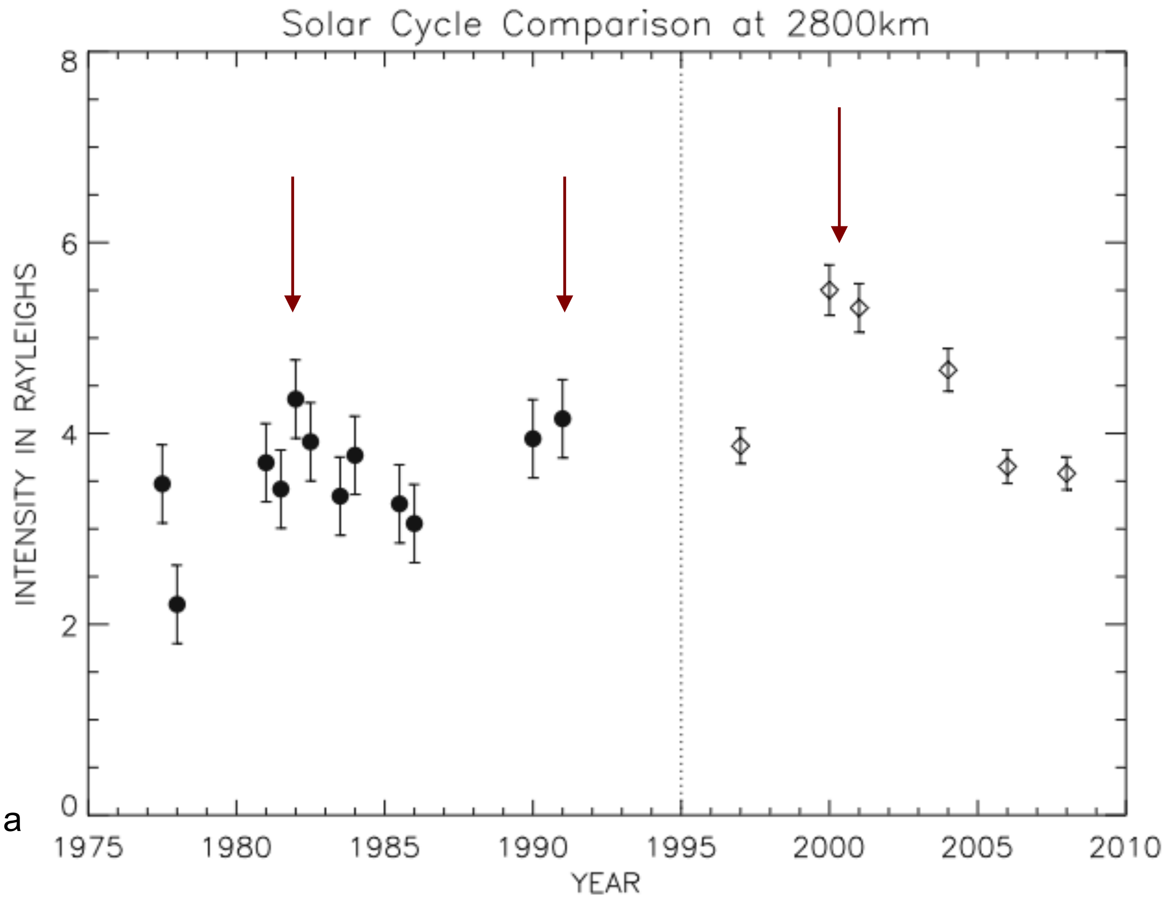


Fig. a

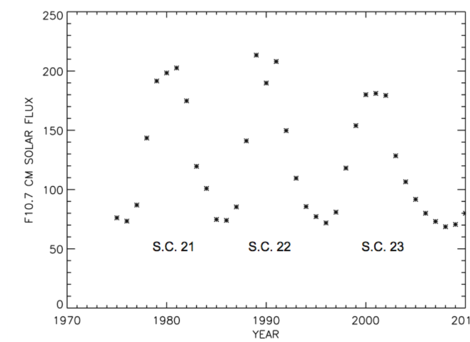


Fig. b

Yearly averaged F10.7 cm flux

- Figure a: Hα column emission intensity at a mid-range shadow altitude vs. year. Observations on the right were taken with WHAM and those on the left were taken with the scanning "pre-WHAM" Fabry-Perot. Error bars indicate uncertainty in the determination of the relative intensity. Each point represents multiple nights and spectra.

The data suggest that there may be upper thermospheric H increases larger than would be accounted for by increases in greenhouse gases.

Conclusions

- Carbon dioxide cooling, as well as methane changes to the source species for hydrogen, both lead to predicted increases in upper thermospheric H
- The modeled response of H to greenhouse gases depends on the solar cycle.
- The modeled increase in the absolute H density due to GHG doubling is greater at min. This result suggests that a secular trend due to greenhouse gases would be easier to detect at solar minimum.
- Modeled hydrogen is greater in the lower thermosphere at solar maximum and at upper thermospheric altitudes at solar minimum.
- The response of the modeled upper thermospheric hydrogen to carbon dioxide cooling and to the solar cycle is consistent with a response to cooling temperatures.
- The WI Northern hemisphere data set indicates solar cycle variation in the H-alpha emission and an increase between solar maxima from solar cycle 22 and 23.
- Experimental and analysis factors are unlikely to account for the underlying increase.
- These sensitivity studies suggest that the magnitude of the apparent observed underlying increases in the thermospheric H airglow emissions are larger than would be accounted for by GHG increases and that other processes may contribute to this increase.

Ongoing/Future Work

- Use of the NCAR Whole Atmosphere Community Climate Model (WACCM) to more realistically investigate lower to upper atmospheric coupling, timescales, & the influence of dynamics and geographic variation on the solar cyclic and climatic response of upper atmospheric hydrogen.

- Refanalyzing solar cycle 22 observatons using updated spectral fitting procedures, the new tropospheric scattering correction code and information about the Galactic emission from the WHAM Galactic map.

- Adding additional observations to the WI long timeline data set.

- Use of WACCM and WACCM-X to study possible correlations between data sets at different altitudes: methane, stratospheric water vapor, noctilucent clouds, upper thermospheric H

Thank you!